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SEAL COATS AND SURFACE TREATMENTS ARE AN ENGINEERING CHALLENGE

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Asphalt surface treatments and seal coats provide wearing surfaces for many of our State Highways. Asphalt surface treatments provide the wearing surface to stone and gravel base courses and are the only justifiably economical surface for many of our State and county highways. Seal coats are applied to many of our road mix pavements and to our hot mixed asphalt pavements as a means of delineating the roadway surface or to provide a non-skid surface.

A distressingly high percentage of our surface treatments and seal coats are providing only a fraction of the serviceability of which they should be capable. In fact, seal coat operations have been considered an art rather than subject to any engineering decisions. Asphalts and aggregates are both common construction materials and engineers should be familiar with their properties. However, it appears that what is acceptable as a seal coat or surface treatment varies greatly and in general, the level of performance expected has been far too low. Even though they are on top, exposed for everyone to see, there has been a tendency to be satisfied with a low standard of design and workmanship that would not be tolerated with any other portion of the finished roadway.

The foremost serious defects in seal coats and surface treatments are streaking from the use of too much or too little asphalt with the loss of cover coat. These defects detract from the appearance of the roadway, and impair the serviceability of the road. These defects can and do occur in surface treatments or seal coats regardless of the nature of the asphaltic material or the cover aggregates employed. They have been observed on projects where the binder is an asphalt cement, a cutback asphalt, or emulsion; and they have occurred where cover coat aggregates are of the very best quality.

It is our intention here to discuss each of the factors affecting the performance of surface treatments and seal coats. It is hoped this discussion will provide information which will help get a higher percentage of serviceable surface treatments and seal coats than we have obtained in the past and of minimizing as much as possible defects in these treatments.

PURPOSE AND TYPE OF SURFACE TREATMENTS AND SEAL COATS

The purpose of placing an asphalt surface treatment on a crushed gravel or stone base is to provide a road or highway with the least expensive type of surface which is dust free and which will prevent raveling. In many instances these surface treatments are the only economically justifiable type of treatment available. Asphalt surface treatments generally consist of a prime coat upon which one or more seal coats are to be applied.

A seal coat, on the other hand, is applied to an asphalt treated surface, either a prime coat or an asphalt pavement. A seal coat therefore performs other functions besides providing a dust free surface.

The seal coat should be applied to fulfill certain needs of the pavement or of the travel way before it is justified and is used. Generally a seal coat is applied to an existing asphalt surface to: (1) seal out moisture and air; (2) rejuvenate a dry or weathered surface; (3) improve skidding characteristics; (4) improve visibility or delineation; and (5) build up a pavement or improve the riding quality.

Surface treatments on gravel or stone bases can vary considerably in practice. Idaho has adopted four types as standard varying their use due to traffic volumes and intended service life.

Type "A" surface treatment shall be a one course treatment consisting of an application of asphalt material and cover coat material. This treatment is considered for temporary use only and is not intended for permanent surfacing.

Type "B" surface treatment consists of a prime coat followed by a seal coat. This treatment is considered as a standard surface treatment and often is the only wearing surface applied on low traffic roads.

Type "C" surface treatment is a two course treatment each consisting of the application of asphalt material and cover coat materials. This treatment is heavier than Type "B" and will generally provide a longer lasting surface.

Type "D" surface treatment consists of a prime coat and two applications of asphalt material and cover coat materials. It is the heaviest and most durable of the surface treatments.

The kind of seal coat to be used is selected depending upon the purpose for which the seal is to be placed. Among the various type of seal coat available are:

Fog Seal is a single shot of asphalt material in a very light application generally of 1/10th gallon per square yard or less without a sand cover. This seal is used in the preparation for heavier applications of asphalt and chips where the pavement surface has deteriorated to the extent that too much absorption of asphalt into the dry pavement would cause failure of the final seal coat. It is also used to provide a roof to a permeable pavement where a regular seal coat is not always desirable. It has been used to seal the surface of asphalt hot mixed pavements constructed late in the fall where inadequate compaction is sometimes responsible for a slight raveling during the following winter. Fog seals must be used with discretion and caution. The are used only to correct defects that exist in existing pavements.

Slurry Seal Coat consists of a mixture of sand and a bituminous emulsion mixed to a fluid consistency which is spread over the roadway surface. The slurry seal coat is used to rejuvenate an old asphalt pavement that is subject to raveling and undergoing serious deterioration. The slurry seal will also seal over minor cracking and will fill minor depressions in the roadway surface giving an improvement to the riding qualities. It should not be considered as a wearing surface.

Sand Seal Coat is generally given to a deteriorating asphalt surface which is undergoing raveling in order to enliven the surface and to provide a non-skid treatment without placing heavy, larger chips which may be detrimental to the texture of the roadway. Sand seal coats are generally used in urban sections or on airport runway pavements.

Standard Seal Coat consists of an application of asphalt material and a 3/8, 1/2 or 5/8 inch cover coat material placed upon the roadway surface. These seal coats are generally used to provide a non-skid surface or to provide some delineation between the travel way and shoulders. A coarse cover coat material sometimes may be used on shoulders to delineate the shoulder from the travel way and also provide an audible noise within the automobile to awaken sleepy drivers should they drive off onto the shoulder unintentionally.

Plant Mixed Seal Coat is a hot mixed seal coat that has been used to resurface roughened, old pavements in need of an improved riding surface. These pavements, while perfectly stable, have much to be desired for serviceability due to the rough surface of the roadway. The hot mixed seal laid by means of a paver will materially improve the riding quality of these surfaces.

SELECTION OF ASPHALTS AND AGGREGATES

Bearing in mind these various treatments, it is necessary to select an aggregate that is appropriate for use and an asphalt that will provide for retaining the aggregate or for rejuvenating the surface, whichever is the intended use of the seal coat. The selection of asphalt and of cover coat material is a joint problem; that is, the cover coat aggregate must be considered while selecting the asphalt and if the asphalt is the primary need for the road surface, then a cover coat material appropriate for use with the asphalt must be chosen.

Several factors, however, for selecting asphalt and aggregate combinations are of primary concern and will be treated separately.

Selection of Aggregates - General

The aggregates to be used for seal coat work will differ depending upon the type of treatment to be provided. Sands can be used for a sand seal or with a slurry seal. A stone chip will be used for the standard type cover coat application, and a graded type of aggregate will be used for the hot mixed surface treatment or seal coat. Sand and stone for any cover coat material should be clean, durable, hard and tough and possess the properties of adhering to asphalt or be hydrophobic in character. Sands will generally be of concrete sand quality.

It is highly desirable that a stone cover coat material be of a single size aggregate gradation, except for the slurry or the plant mixed treatment. Generally, graded materials, because of the range of particle sizes, cause bleeding or streaking and also a loss of cover stone. Cover coat materials used in the plant mixed seal coat are a graded material, but due to hot plant mixing and paver laying are actually a plant mixed surfacing of a special classification.

Aggregates for cover coat material must be clean and should be dry to provide the best bond with the asphalt. During the past many years, it has been common practice due to dusty, dirty aggregates to moisten aggregate stock piles, thereby preventing a dust problem and also assisting in bonding with the asphalt. However, this is making the best of a bad situation. A clean, dry, material will bond most readily with the asphalt. Water must be evaporating before asphalt will bond to the stone. A coating of dust on each particle will have an effect of preventing good adhesion. Due to poor adhesion, resulting either from dust or from water, the aggregate particles are more readily displaced by traffic. In some instances, with a heavy viscous binder such as a 3,000 grade or an asphaltic cement, a dusty aggregate may completely prevent adhesion. A combination of dust and moisture will lengthen the delay of good adhesion between the aggregate and the asphalt, further increasing the possibility of loss of cover aggregate because of traffic abrasion.

A single size aggregate by reason of the more careful screening necessary to obtain a single size stone materially aids in removal of any dust or fine sand that prevents the bond. However, some aggregates have a dust coating that can only be removed by washing. The No. 200 sieve is inadequate in showing how much of this dust exists on a stone. A recent test developed by California for use in measuring the cleanliness of a coarse aggregate for concrete is equally applicable for use in measuring cleanliness of cover coat materials. This test is under investigation and modification by the Idaho Materials Laboratory and has been run for approximately two years by most of their field testing personnel. This test consists of washing a standard size sample of aggregate in a standard volume of sand equivalent solution and then permitting this solution to settle and measure the column of precipitated clay in the solution. Any coating on the aggregate is thereby removed and readily measured.

Selection of Asphaltic Materials - General

The selection of asphaltic materials for surface treatments and seal coats must satisfy the following requirements:

1. It must be fluid enough at the time of spraying for a uniform application inch by inch across and along the road surface.
2. Asphalts used in prime coat treatments must be sufficiently fluid to penetrate into the base course and yet provide sufficient adhesion to bond the surface tightly.
3. The binder must be fluid enough at the time the cover coat

aggregate is applied to develop rapid wetting and fast initial adhesion between the binder and the aggregate and to the underlying road surface.

4. The binder must be viscous enough to retain the cover aggregates in place when the finished seal is opened to traffic.

DESIGN OF SEAL COATS AND SURFACE TREATMENTS

A selection of the type of seal coat that is needed to most efficiently perform the function intended must be made using the best engineering judgment, knowledge of materials, project conditions and seasonal variations of weather and traffic volumes and control.

Fog Seal consists of a single application of asphalt material to an existing asphalt surface without aggregate cover and is used where it is necessary to rejuvenate dry absorptive pavements. It is also used to seal new pavements laid in the late fall, that will not have the benefit of traffic compaction before cold weather sets in. The treatment should be used only when the existing surface is sufficiently porous to absorb the greatest portion of the sealing material. Normally, we should use 0.05 to not more than 0.10 gallons per square yard of MC-70, RC-70, or a dilution of slow setting emulsion (SS-1). In using an emulsion, it should be diluted in the ratio of one part emulsion to one or more parts water and the dilution applied at a rate less than that which will cause surface flow. An application study of this type of treatment using a dilute emulsion was made last year on the Kansas Turnpike. On this experiment, it was found that 0.05 gallons per square yard of liquid could be applied without noting an appreciable amount of surface flow. Also, in checking concentration, it was found that the pavement could absorb 0.005 of a gallon of residue. This, then, gave a design mixture of 200 gallons of SS-1 emulsion to 800 gallons of water. The mixture was applied at 0.05 gallons per square yard.

Slurry Seal consists of a thin application (1/8 of an inch or less) of a mixture of fine aggregate, slow setting emulsified asphalt and water. The slurry treatment is designed to reduce maintenance and retard surface deterioration. It is intended to fill all cracks in pavements which show block or map cracking, but have no indication of base movement or base failure. It also fills the surface voids in badly raveled pavements, performing a minor leveling action. The completed surface has the advantage of providing no loose stone, thereby, saving on windshields. Also, from the construction standpoint, a slurry seal can be very rapidly placed. The Design of a slurry seal utilizes a sand as shown below:

Sieve Size	Percent Passing
No. 4	100
No. 8	95-100
No. 16	70-90
No. 30	50-80
No. 50	30-50
No. 100	10-25
No. 200	5-15

The sand equivalent should not be less than 40. A filler is often necessary and if required, should be Portland cement, hydrated lime or limestone dust. The amount of filler used is dependent on the type and gradation of aggregate. Normally Portland cement is limited to about $1\frac{1}{2}$ percent, limestone dust to 2 percent and hydrated lime to 4 percent.

The sand is mixed with an emulsified asphalt SS-1 or SS-1h and water. Normally the emulsion content of the mixture is 20 to 25 percent by weight of the total weight of the aggregate plus emulsion excluding added water. Water is added, generally in one gallon per 100 pounds of sand to produce a relatively free flowing "creamy" consistency as required by a slurry mixture. The mixture should be of such a consistency as to flow in a wave approximately two feet ahead of the strike-off squeegee.

Prior to application of the slurry seal it is strongly recommended that an application of 0.05 to 0.10 gallons per square yard of a dilute solution of one part emulsion to three parts water be used as a tack coat rather than using water alone.

The choice of SS-1 or SS-1h is dependent upon the time permitted for complete curing. The SS-1h cures more rapidly (about 4 hours) than the SS-1 which will require a day or more to set completely, although either can carry traffic within two hours or even less.

Sand Seal Coat consists of a single application of asphalt material to an existing pavement with a sand aggregate cover coat. Generally, the sand seal coat is used for the same purpose as a fog seal or slurry seal with the added benefits of better non-skid properties. A RC-250 is most often used and applied at about 0.12 to 0.15 gallons per square yard with a cover of about 10 to 12 pounds of sand.

It is often used on city streets, parking areas, airport runways and for similar uses where a standard seal coat is objectionable and the plant mixed seal coat is not warranted.

Standard Seal Coat consists of a single application of asphalt material to an existing pavement or prime coat with an aggregate cover coat. The first systematic and detailed study of this type seal coats was made by F. M. Hansen of New Zealand. Although some of the problems studied are peculiar to that area, the fundamental principles established by him are the basis of seal coat designs. Working with single sized aggregates, he established a correlation between the average least diameter (effective size) of the stone and the quantity of cover coat aggregate required per square yard for complete coverage. He determined that the quantity of asphalt material required was related to the void content of the compacted cover coat material. In his work, the surface of the pavement was primed or fog sealed to a standard condition before placing the seal coat so absorption of the asphalt by the pavement could be neglected in determining the application rate.

Table No. 1 gives desirable aggregate gradations.

Table No. 1

Sieve Designations Square Openings	Percentages by Weight Passing Sieves					
	3/4" - No. 4	5/8" - No. 4	1/2" - No. 4	3/8" - No. 10	Sand.	5/8 to Dust
3/4"	100					
5/8"		100				100
1/2"	30-75		100	100		90-100
3/8"		20-70	40-80	95-100	100	
No. 4	0-8	0-12	0-15	10-30	95-100	
No. 6		0-5	0-5			
No. 10				0-6	40-75	0-30
No. 200	0-2	0-2	0-2	0-2	0-3	0-5

The aggregate shall have a loss of not more than 40 percent in the Los Angeles Abrasion test. The cleanness test being studied by Idaho indicates a probable specification limit of not less than 75.

In Idaho, a modification of the Kearby Method is in use and is designated as Idaho Method of Test T-60. The calculations of asphalt material and cover coat aggregate by this method use the basic principles developed by Hansen and modified by Kearby of the Kansas Asphalt Association. Briefly, the quantity of asphalt and cover coat aggregate is calculated using the effective size of the aggregate, specific gravity, weight per cubic foot and embedment desired. The computations are aided by a graphical chart shown in Figure 1.

The average particle size is computed by multiplying the percent of each size aggregate expressed as a decimal, by the median size value obtained from Table II.

Table No. 2

Median Size, Inches Between Different Test Sieves							
To \ From	1"	5/8	1/2	3/8	No. 4	No. 6	No. 10
3/4"	0.88						
5/8"	0.81						
1/2"	0.75						
3/8"	0.69	0.50	0.44				
No. 4	0.59	0.41	0.34	0.28			
No. 6	0.57	0.38	0.32	0.26	0.17		
No. 10	0.54	0.35	0.29	0.23	0.13	0.11	
Dust	0.51	0.33	0.27	0.21	0.11	0.08	0.04

ASPHALT - APPLICATION - RATE CHART

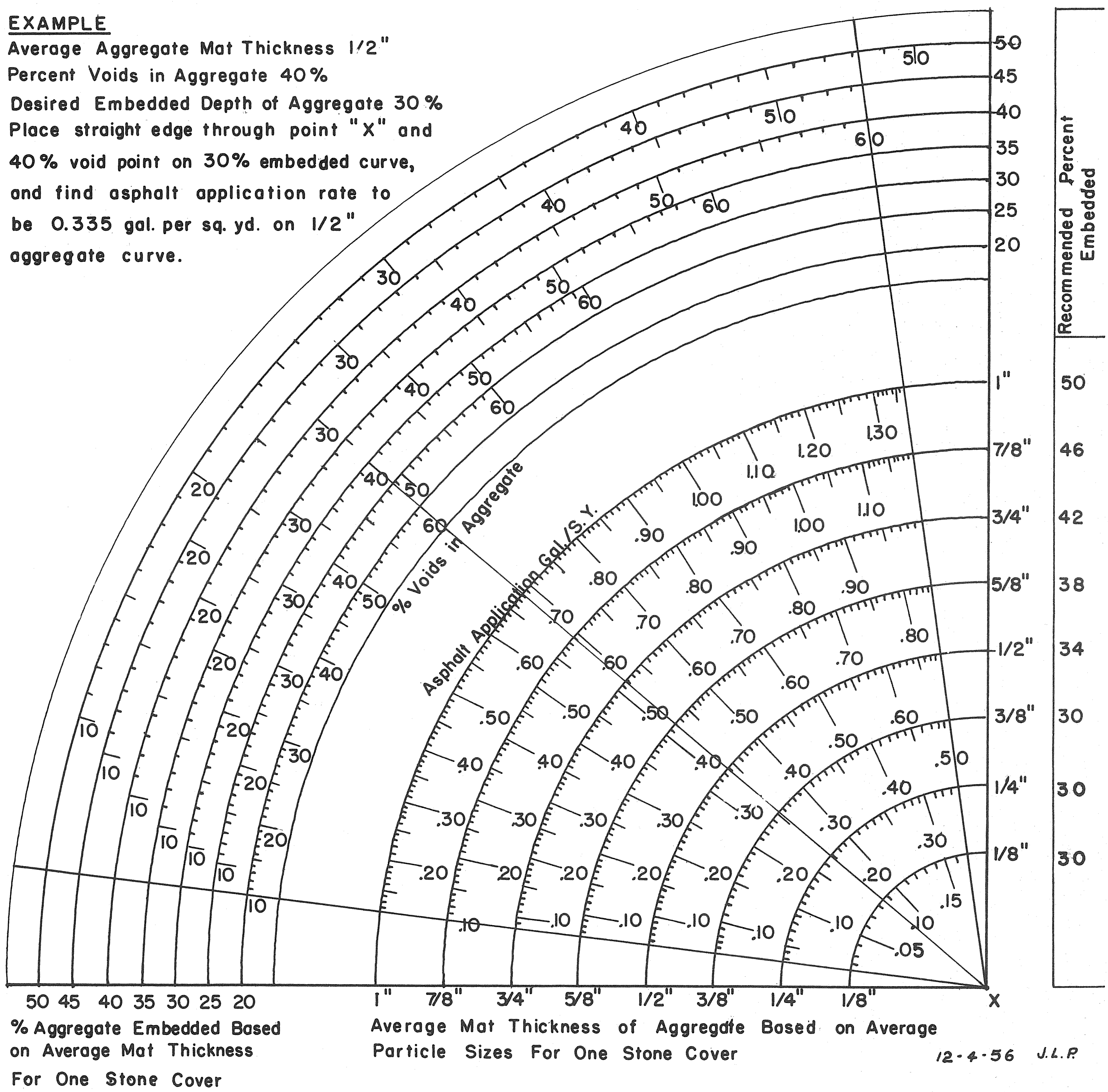


FIGURE 1

EXAMPLE: ½" to No. 4 Cover Coat - WT/CF 90, SpGr = 2.65

Sieve	% Passing	Computation
Pass 1/2"	100	
		0.44 x 0.20 = 0.09
Pass 3/8"	80	
		0.28 x 0.71 = 0.20
Pass No. 4	9	
		0.17 x 0.06 = 0.02
Pass No. 6	3	
		0.08 x 0.03 = 0.00
Total		0.31

Using the chart shown in Figure 1. the average mat thickness is then 0.31 inch or just slightly less than 3/8 inch. The column on the extreme right gives the recommended percent embedment which in this instance is 30 percent. The specific gravity and weight per cubic foot give us:

$$\frac{90}{62.4 \times 2.65} = 54\% \text{ Solids or } 46\% \text{ Voids}$$

Entering the chart at the bottom left at 30 percent embedment and following the curve to 46 percent voids, draw a line through point "x" (the center of the Circle). Read the asphalt application for a 3/8" mat thickness (0.29 gals/sq. yd.) and for a 1/4" mat thickness (0.19 gals/sq. yd.). Interpolating between these figures for 0.31" thickness then gives us:

$$\frac{(0.31-0.25)}{(0.375-0.25)} \times (0.29-0.19) + 0.19 = 0.24 \text{ gals/sq. yd.}$$

This quantity does not provide for water loss in an emulsion, loss of volatile in a cutback, or absorption within the stone or by the pavement.

Compute the application rate of cover coat material as follows:

$$\frac{36}{\text{Ave. Mat. Thickness}} = \text{Sq. Yds. surface covered per cubic yard of cover coat}$$

or

$$\frac{36}{0.31} = 116 \text{ sq. yd. per cu. yd.}$$

If it is desired to know the pounds per square yard, this can be computed as follows:

$$\frac{\text{WT/CF} \times 27}{\text{Sq. Yds. Covered}} = \frac{90 \times 27}{116} = 21 \text{ lbs./sq. yd.}$$

An allowance of 15 percent for whip-off by traffic should be made, increasing this to 24 pounds.

Another method, much simpler, but not as accurate when using materials of very high or low specific gravity can be used as a check. The effective or average size particle must be computed as for the previous method. The asphalt quantity is then computed as follows:

$$\text{Asphalt gals./sq. yd.} = 0.7 \times \text{Eff. Size} + G$$

Where G = 0 for Asphalt Cements

= 0.03 for RC and MC Asphalts

= 0.10 for Emulsified Asphalts

Using the same gradation and average size as in the previous example and a RC-800

$$\text{Asphalt gals./sq. yd.} = 0.70 \times 0.31 + 0.03$$

$$= 0.25 \text{ gals./sq. yd.}$$

This checks within 0.01 gal. per square yard which is satisfactory. The quantity of Aggregate to be applied is computed as follows:

Aggregate lbs./sq. yd. = 80 x Eff. Size

Using the same data again:

Aggregate lbs./sq. yd. = 80 x 0.31 = 24.8 lbs.

The selection of asphalt and aggregate for any project is dependent upon many factors and is so inter-related that the choice of one governs the selection of the other. The surface to be treated, purpose of treatment, season of the year and character of available aggregates will also affect the choice of asphalt and aggregate. Table No. 3 shows recommendations for cover coat material for various surfaces.

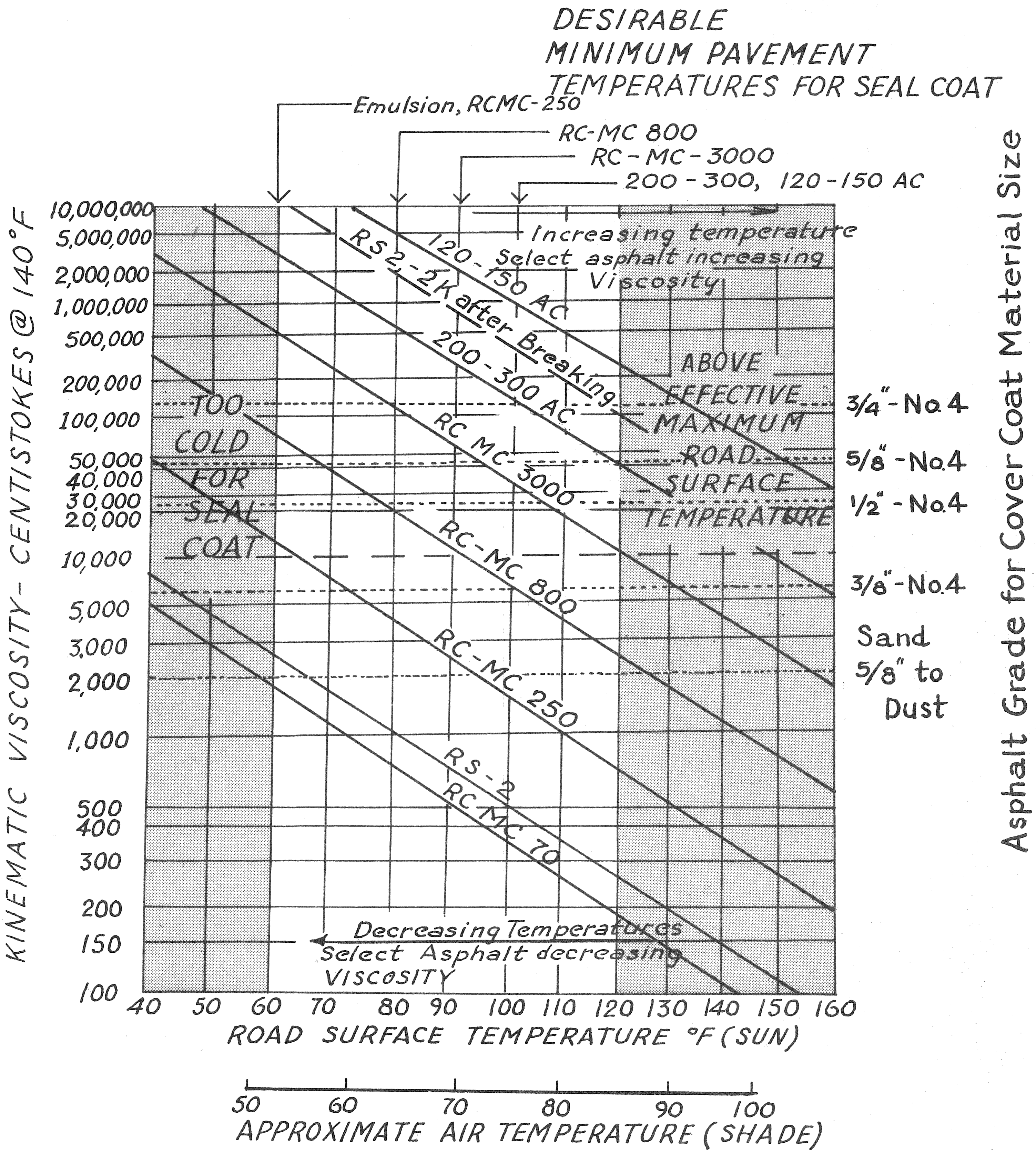
Table No. 3

Surface	Aggregate Size 5/8-4	1/2-4	3/8-10	Sand	5/8-Dust
Urban Streets			X	X	
Interstate Highways		X	X		
Primary Highways		X	X		
Secondary Highways (Roadmix)	X	X			
Surface Treatment of Base	X(1)	X(2)	X(2)		X(1)
Airport Runways			X	X	

(1) First Application

(2) Second Application

Figure 2 gives recommendations of asphalt grade for varying surface temperatures for various sizes of cover coat material. The viscosity of the asphalt is controlled by the temperature of the surface to which it is applied. Seasonal variations, spring or late summer, when compared with midsummer may influence one to choose a different grade. This can be illustrated with a $\frac{1}{2}$" - No. 4 cover coat and 100° F. surface temperature



SELECTION OF ASPHALT GRADE FOR GIVEN ROAD SURFACE TEMPERATURES & IDAHO SPECIFICATION COVER COAT MATERIAL

FIGURE 2

which indicates an RC-MC 3000 grade and for a temperature of 70° F, an MC-RC 800 grade. The recommended surface temperatures for the various grades is given at the top of Figure No. 2. Realizing that June and September temperatures are commonly below 70° will illustate the limitations of using paving grade asphalts to the midsummer season only. Noting the difference between road surface temperatures in the sun and realizing that temperatures in the shade will approach air temperatures in the shade, indicates that failures often occur in the shade of trees.

Open Graded Plant Mix Seal

The open graded plant mix seal coat consists of a crushed aggregate mixed with asphalt cement and placed on the roadway by means of pavers. This seal coat is used when difficult situations make the standard seal coat impractical. Very high traffic volumes where traffic control is difficult, make this type seal especially desirable. Other conditions, such as wide temperature variations, short sections of sun and shade, a surface texture making difficult adhesion and where some leveling is desired, make an open-graded plant mix seal coat a desirable solution.

The mixture for an open-graded plant mix seal coat consists of a crushed aggregate meeting the following gradation:

Passing	1/2"	Sieve	100%
Passing	3/8"	Sieve	95-100
Passing	No. 4	Sieve	20-40
Passing	No. 10	Sieve	5-15
Passing	No. 200	Sieve	0-3

The aggregate is mixed in a paving plant with approximately 5.5 to 7.0 percent of 60/70 or 85/100 penetration asphalt and is spread on the surface to approximately 3/4" depth with a paving machine. One coverage of a steel wheel roller is all that is required for compaction. The quantity of asphalt for the seal can be computed from the following formula:

$$\text{Percent Asphalt} = 1.5\ k_c + 3.0$$

Where k_c = Value from CKE test = Coarse aggregate absorption of SAE 10 lubricating oil.

PRIOR TO THE APPLICATION OF THE PLANT MIX SEAL COAT
A TACK COAT IS REQUIRED

The tack coat consists of an application of asphalt material to an existing surface to assure a thorough bond between the superimposed construction and the old surface. The tack coat should consist of not more than 0.10 gal. per square yard very uniformly applied to prevent lubrication or slippage. Generally, a mixture of one part emulsified asphalt SS-1 and one part water applied within the range of 0.05 to 0.10 gals. per square yard is recommended. An RC-70 may be used, but the limited amount to be used often creates difficulties.

Surface Treatment

A surface treatment consists of one or more applications of asphalt with or without aggregate coverages to any surface. We wish to limit the definition to the application to crushed gravel or stone base courses where the surface treatment serves as the wearing course. This definition conforms to the common usage in this area. The surface treatment generally consists of a prime and one or more seal coats. Also included are heavier than normal applications of asphalt with cover coat without a separate prime coat. In this usage, the asphalt serves both as a prime coat and bond for the cover coat.

The prime coat consists of the application of a light, liquid asphalt, applied directly to the crushed gravel or stone base material. The object of priming is to coat and bond the loose aggregate particles, waterproof the surface, harden and toughen the surface and promote adhesion between the base and overlying courses.

The grades of asphalt commonly used are MC or RC-70 for average base course materials. The MC-250 grade may be used for the open textured base materials. Generally, the MC-70 is the most frequently used for prime coat.

The quantities of asphalt used may vary over a range from 0.20 to as much as 0.60 gals. per square yard. Generally, about 0.25 to 0.35 gals. per square yard is adequate.

General considerations for selecting the type, grade, and quantity of asphalt material for a prime coat are as follows:

1. Choice of Type

   Use MC for the denser, tighter bases, and RC for the sandy, open-graded bases. The MC should be used in all instances where any plastic fines are evident or the sand equivalent is low.

2. Choice of Grade

   The 70 grade asphalt is used for the denser bases or where 5 percent or more material passes the No. 200 sieve and normally twice as much material will pass the No. 40 sieve as passes the No. 200. The 250 grade should be used for very open-graded material lacking in fine sand, i.e. less than 10 percent passing the No. 40 sieve.

3. Quantities of Asphalt

Dense graded base courses will rarely absorb or permit penetration of more than 0.25 to 0.30 gal. per square yard. Quantities will increase as the base becomes more open textured. The very open-graded bases requiring the grade 250 will require in excess of 0.35 gals. per square yard. These quantities are for prime treatments not to be blotted with sand or surfacing material. The actual quantities to be applied must be left for field determination as no design method is known to be in use.

The application of a standard seal coat to a properly primed base constitutes the Type "B" surface treatment as used and specified by Idaho. The application of two standard seal coats to a primed base constitutes Idaho's Class "D" Surface Treatment. The selection of materials and design of seal coats for this surface treatment would follow the recommendations for standard seal coats previously discussed.

Two other surface treatments are used in this area, each omitting the prime coat. These require the first application of asphalt to serve the dual purpose of prime coat and seal coat asphalt.

One of these, Idaho Type "A", consists of one application of asphalt and one application of cover coat material. Idaho Type "C" consists of two applications of asphalt, each given an application of cover coat material.

The Type "A" surface treatment and the first application of the Type "C" surface treatment will normally use a heavy application of MC-250 asphalt. This application is covered with a graded cover coat material having the following gradation:

Sieve Size	% Passing
5/8" sq.	100
1/2" sq.	90-100
No. 4	30-65
No. 10	10-30
No. 200	0-5

The above material should have a minimum sand equivalent of 45.

This gradation and sand equivalent requirement is different than that in the 1960 Idaho Specifications, but it is believed necessary due to the use of the four grade system of liquid asphalts. The MC 800 grade, if having a viscosity at the top limit is too heavy for normal use. Therefore, the MC-250 is recommended, but assurance of a minimum quantity of fine material is necessary.

The amount of asphalt used in the Type "A" surface treatment and first application for the Type "C" is determined as follows:

(1) The volume for computation purposes in one square yard is the maximum size of the cover coat material times 0.75 cu. ft. (the 0.75 is the volume if one inch thick.)

(2) The volume of asphalt is then the value obtained in Step 1 multiplied by the factor obtained from Table No. 4.

(3) The volume of asphalt obtained in Step 2 is multiplied by 7.5 to convert to gals. per sq. yd.

The factor from Table No. 4 recommended for use in Step 2 above is the 55% column for Type "C" surface treatments and the 60% column for Type "A" surface treatments. The use of these columns does not take into account the openness or tightness of the base course, but assumes an average condition.

Assuming a 5/8" maximum aggregate and low volume of traffic with the factor for Type "C" surface treatment (55%) we compute the first application of asphalt as follows:

(a) Volume of 1 sq. yd. = 0.75 x 0.625 = 0.4688 cu. ft.

(b) Volume of Asphalt = 0.4688 x 0.110 = 0.0516 cu. ft.

(c) Convert to Gallons = 0.0516 x 7.5 = 0.39 gals./sq. yd.

Table No. 4

ASPHALT QUANTITY FACTORS FOR VARIOUS USES

Principal Uses of Surface Treatments	% of Volume to Be Filled					
	40%	45%	50%	55%	60%	65%
Parking Areas & Seldom Used Areas	0.088	0.099	0.110	0.121	0.132	0.147
Low Volumes of Traffic	0.080	0.090	0.100	0.110	0.120	0.133
Medium Volumes of Traffic	0.076	0.085	0.095	0.104	0.114	0.126
Large Volumes of Traffic	0.072	0.081	0.090	0.099	0.108	0.120
Very Heavy Traffic	0.068	0.076	0.085	0.093	0.102	0.113

In determining the amount of aggregate to be used for Type "A" or first application of Type "C" surface treatment, it has been found that about 80 percent of the weight obtained by multiplying the volume obtained in Step (a) by the weight per cubic foot loose of the cover coat aggregate. For example:

Vol. of Agg. (Step (a) above) = 0.4688

WT/cu. ft. of loose aggregate = 100 lbs.

WT/sq. yd. = 0.4688 x 100 x 0.80 = 37 lb./sq. yd.

The second application of asphalt and cover coat materials for the Type "C" surface treatment will follow the computations shown for the standard seal coat for type asphalt and size of cover coat to be used making no allowance for absorption of pavement.

Use of Asphalt Additives

No discussion of seal coats or surface treatments is complete without mention and discussion of additives or anti-stripping agents. These products are advocated by some people for use to promote the adhesion of the aggregate and asphalt. It is well known that some aggregates do possess hydrophylic or "water loving" characteristics and these additives are designed to change these characteristics. Unfortunately, there are no well defined or completely reliable tests for this purpose. Tests that are used can at best be considered only to indicate tendencies. Also, it is known that the more liquid grades of asphalt are more susceptible to stripping than the heavier or more viscous asphalts once a bond has occurred. It is also known that a particular additive may work with one stone and not with another. This means that selection is difficult and a search for an acceptable additive is necessary. The additives on the market will all benefit some aggregate, but none will benefit all aggregates. Laboratory tests are necessary to select the additive to use and these tests are not as yet 100 percent selective.

CONSTRUCTION PRACTICES

The great majority of problems in seal coat and surface treatment work arise in the actual construction rather than in the design, specification or material used. An observant, alert inspector, and competent contractors' crew can assure that everything possible is done to obtain a good job. Essential to superior or even good work is proper equipment in good working condition, properly prepared surfaces to be treated, good construction practices with recognition of temperature controls and weather.

Preparation of Existing Surface

In seal coat work it is necessary that some preparation of the existing surface take place, and the authors suggest the following: (1) unless they can be corrected by a sprayed skin patch, all defective areas in the old surface should be cut out and replaced with sound material; (2) where broken edges have occurred, the existing old asphalt surface should be restored to the required width and cross-section with pre-mix material; (3) any hardened clay or other foreign material should be removed; (4) rich flushed areas should be corrected by either burning off and scraping the surface or by use of a heater planer. It is important that the old surface be brought to a reasonable degree of uniformity by correcting flushed areas and "hungry" areas before the seal coat is applied.

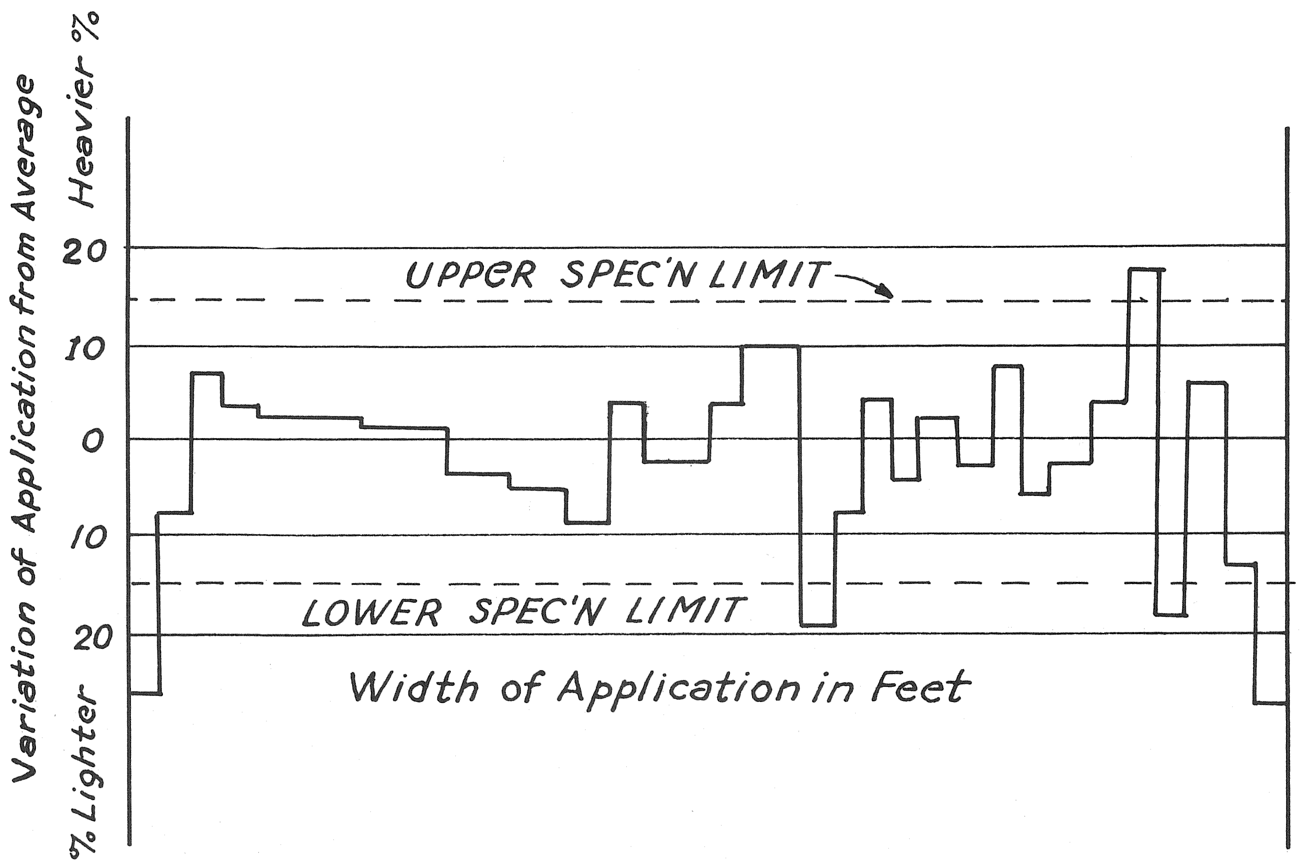
In surface treatment work, if the base is narrow, or if the cross-section or profile is out of shape, it may be necessary to add some new base material to a granular base course. The road should be scarified and the new material added and mixed into the base. Soft spots should be excavated to the depth and width necessary to make sure that none of the soft material is left in the road structure. New material is added in uniform layers, not exceeding three inches and compacted to a density equal to that of the surrounding base.

Distributors

The most important piece of equipment on a seal coat or surface treatment project is the asphalt distributor. It is made for the express purpose of applying the asphalt binder to a surface in exact quantities and to maintain the special rate for the entire load.

There are many makes and models of distributors used. The instructions of the manufacturer should be consulted in adjusting, operating, and inspecting the machine. The distributor should be calibrated and equipped with a dip stick marked in gallons per inch of length to check the quantity of material in each load, and the amount used for any application. The distributor should be equipped with a thermometer well and an accurate thermometer to determine the temperature of the asphalt at the time of application. A uniform rate of application of asphalt on the surface requires that; (1) the asphalt must be at the proper viscosity usually 40 to 60 seconds, Saybolt-Furol, or 80 to 120 centistokes Kinematic; (2) the correct pressure must be maintained continuously and uniformly throughout the full length of the spray bar to provide no greater variation than 15% transversely and no more than 10% longitudinally by test; (3) the nozzles must be set at the proper angle, usually 22 to 30^{o} with the longitudinal axis of the spray bar to prevent the spray fans from intermixing or interfering with each other; (4) the angle of application with the surface should be about 90^{o}; (5) the nozzles must be set and maintained at the proper height above the surface to assure a proper lap of the spray fans; and (6) the speed of the distributor must be constant. See Figures 3 & 4 illustrating these points.

The speed of the distributor, and on some makes the speed of the asphalt pump, are controlled by a special tackometer, called a bitumeter. It consists of a rubber tired wheel mounted on a retractable



DISTRIBUTION OF ASPHALT ACROSS BAR

FIGURE 3

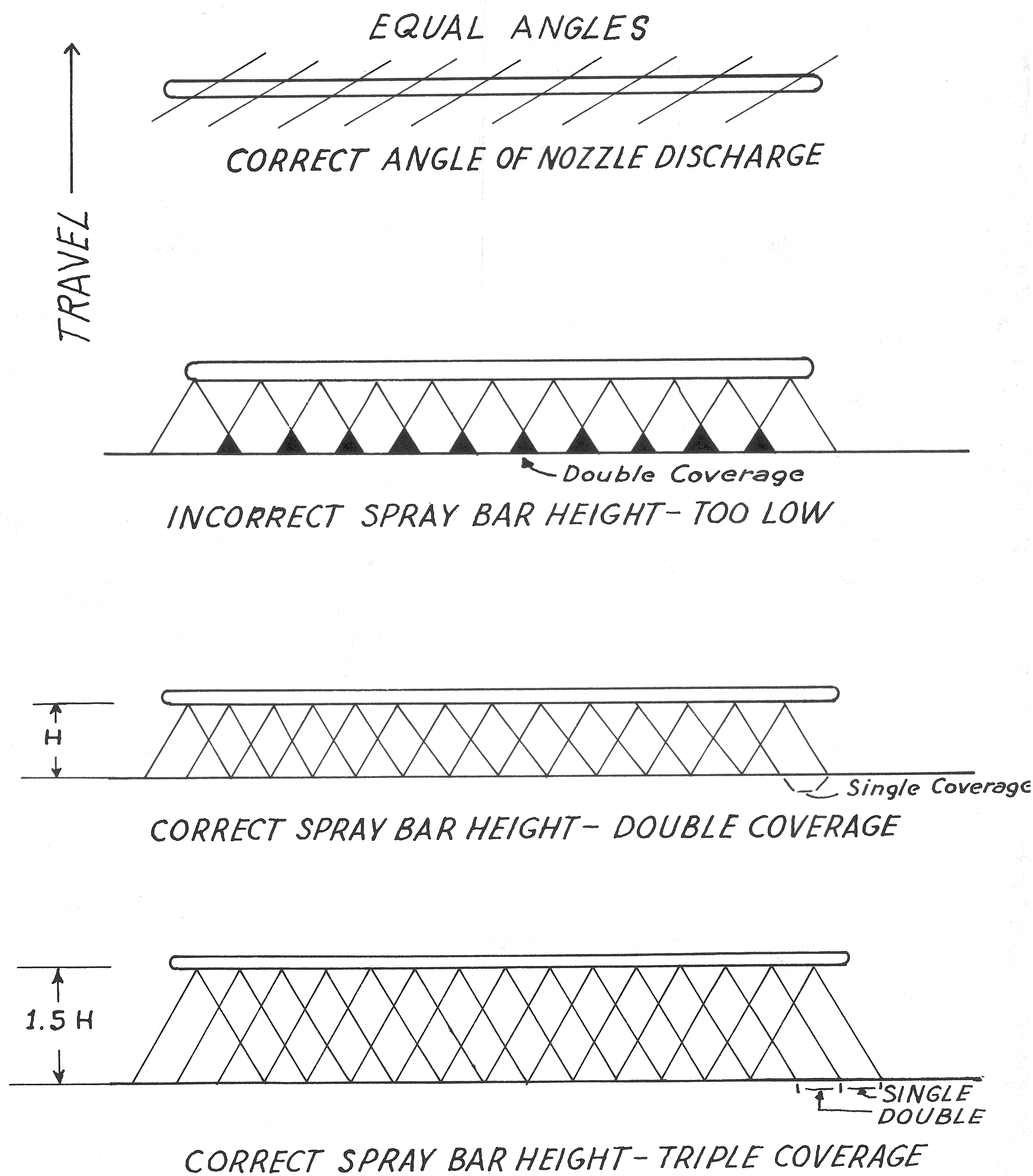

EQUAL ANGLES
TRAVEL
CORRECT ANGLE OF NOZZLE DISCHARGE
Double Coverage
INCORRECT SPRAY BAR HEIGHT- TOO LOW
H
Single Coverage
CORRECT SPRAY BAR HEIGHT- DOUBLE COVERAGE
1.5 H
SINGLE
DOUBLE
CORRECT SPRAY BAR HEIGHT- TRIPLE COVERAGE

FIGURE 4

frame with a cable leading to a speedometer in the vehicle cab registering the rate of travel in feet per minute.

The distributor speed desired for any rate of application can be determined with the following formula:

$$S = \frac{9G_t}{WR}$$

Where: R = Rate of Application (gallons per square yard) desired

G_t = Total Application in Gallons Per Minute

S = Speed of Distributor in Feet Per Minute

W = Width of Spread in Feet

Aggregate Spreaders

Next in importance to the uniformity of the application of asphalt, the performance of seal coats and surface treatments is influenced by the manner in which the cover aggregate is applied. All aggregate needed for the planned spread should be on hand before application of asphalt. When the distributor moves forward to spray the asphalt, the aggregate spreader should follow closely. It is essential that the asphalt be covered within about two minutes or the large increase in viscosity that may take place within that time will prevent good wetting and binding of the aggregate. It is also important that the aggregate be spread uniformly and at the proper rate. In a single application, aggregate will not stick more than one particle thick to the asphalt. It is useless and wasteful to apply aggregates at a rate greater than a single layer in thickness. A uniform application rate can be assured with a properly adjusted spreader. The rate of application of the aggregate should be frequently checked by measurement of the square yards covered per cubic yard of material applied.

Rolling

The purpose of rolling is to seat the aggregate in the asphalt and thus promote the bond. The authors recommend that a pneumatic tire roller be used for this purpose. This roller will give a uniform pressure over the entire area while a steel wheel roller will bear only the high spots. It is extremely important that the rolling begin immediately after distribution of the cover coat material and continue until the aggregate is well seated. Idaho requires that the cover coat be given one complete coverage before the application of asphalt is permitted more than 2500 feet ahead of rolling. All rolling should be completed the same day.

A seal coat or surface treatment cannot be overrolled with pneumatic rollers. Steel rollers, however, sometimes crush aggregates and should be eliminated from use if this occurs.

Slurry Equipment

Slurry seals are usually mixed in transit mix trucks, then transferred to a spreader box towed behind the truck which spreads the mixture to the surface. Slurry seal machines are available which will combine all operations into a single unit. They store materials, mix the slurry, deposit it in the spreader box and squeegee it onto the road surface in controlled amounts. These machines mix and spread continuously and the screed is adjustable for thickness of application. As with other types of equipment, slurry seal machines must be calibrated and adjusted for accurate operation. Rolling of slurry seals is not recommended.

Other Equipment

Other pieces of equipment such as motor graders, brooms, hot plants, and pavers are described in the Asphalt Institute's Asphalt Plant Manual and Asphalt Paving Manual and most specifications.

Joints

In standard chip seal and surface treatment work, rough and unsightly transverse joints can be avoided by starting and stopping the asphalt and aggregate spread on building paper. The paper should be placed across the lane to be treated and it should be placed so that the forward edge is at the desired joint location. The distributor, traveling at the correct speed for the desired application rate, should begin spraying on the paper so that when it reaches the exposed surface, the spray bar is making a full, uniform application. A second length of building paper should be placed across the lane at the predetermined cutoff point for the distributor. This will give a straight, sharp transverse joint. It is practically impossible to attain uniform applications of asphalt without use of the paper and should always be required. The paper should be removed and discarded after the aggregate spreader has passed over it. Full width applications of asphalt and aggregate will eliminate longitudinal joints, but in most work, traffic must be maintained and the outer joint is necessary. In order to prevent aggregate from building up on the longitudinal joint, the width of the aggregate spread should be slightly less than the asphalt spread at the joint. This will allow a width which can be overlapped when the asphalt is applied in the adjacent lane.

In slurry seal work, handwork may be eliminated on longitudinal joints by use of carpet or burlap drags on each side of the slurry spreader box.

Temperature Controls and Weather

The temperature viscosity relationships and volume controls on asphalt are important. Asphalt viscosities change greatly with changes in temperature. The viscosity of asphalt is generally doubled for every drop in temperature of about 18°F. and cut in half for each increase of the same amount. This fact applies not only to spraying temperatures, but also to the viscosity of the asphalt once sprayed upon the roadway. Figure 2 shows the temperature of pavement in the sun versus the viscosity for the midrange of each grade of asphalt. A careful look at these lines will show that a change of about 30°F. is the equivalent to changing one grade of asphalt insofar as viscosity is concerned. This means simply that an MC-800 at 100°F. on the pavement or an MC-3000 at 130°F. have the same consistency and neither can be any more tenacious in retaining the cover coat at these temperatures.

This temperature relationship is very important to the success of a seal coat or surface treatment. The asphalt must be sufficiently hot to spray properly. This is generally stated to be a kinematic viscosity of 80 to 120 centistokes. The asphalt chills to roadway temperatures rapidly and once cooled, must remain fluid enough to wet the aggregate and yet have sufficient viscousness to bond the stone to the surface. Large aggregate sizes will require a stiffer asphalt than will sand for the same pavement temperature. Figure 2 again shows the asphalt grade for each size stone used as cover coat. Slightly higher viscosities for work in the warmer areas of the State and slightly lower for the cooler, higher areas can be used. The importance of this chart in selecting the grade to use and in making changes in grade should not be overlooked. Selection of a wrong grade of asphalt for the temperature conditions or size of cover coat aggregate can cause failure of the seal coat or surface treatment.

Another factor which should be mentioned and known to have been the largest contributor to failure is the temperature prevailing after application of the seal coat. Several emulsion seal coats have failed when freezing weather occurred the night following application. It is essential that good weather prevail for some time after the seal coat to permit proper curing of the asphalt material. Hot weather is needed to permit the asphalt to wet and bond the stone. Reduction of viscosity ranges will aid in this respect, but if the weather changes and suddenly becomes very warm, the grade chosen can be too soft. Weather near the end of August in the higher elevations and after about September 15 in the lower elevations becomes especially critical in this regard. In fact, for the month of September, low temperatures below 32° F. can occur anywhere in the State with the possiblities increasing to as frequent as 20 days in the month at the higher elevations such as Stanley and Island Park.

Idaho in 1958 published a bulletin giving temperature and precipitation data for selected locations in the state and is a useful guide.

Traffic Control

Control of the traffic through the project is important to high quality work. This is accomplished by convoying traffic through the project at speeds low enough to prevent any damage to the surface. Normally, these speeds range from 10 mph initially to 25 mph as the aggregate is seated and bonded.

The length of time that traffic should be convoyed over the project depends in part on the weather and the type of asphalt applied. During cool, damp, cloudy, or humid weather convoying must of necessity be continued far longer than during a time when the weather is warm, dry, and sunny. This is to be expected because the cool damp weather delays the evaporation of the moisture contained in the cover aggregate and also the setting rates of the asphalt cutbacks or emulsion.

Should rain fall on a freshly applied seal coat, a cover aggregate is particularly susceptible to being dislodged and thrown off the road by fast traffic. Should rain occur, traffic should, if possible, be kept off of the roadway until the cover aggregate has become dry. If this is not possible, extremely slow convoying of the traffic is necessary and rolling continued until danger of dislodging aggregate has passed.

CONCLUSIONS

Control of quantities and of uniformity of distribution of the material is essential both for asphalt and aggregate. The construction procedures outlined are the best known from many years of experience. Close attention to the several principals outlined can materially aid in obtaining a good job.

In other words, seal coats and surface treatments are an engineering challenge, not an art. It is evident by the fine workmanship and excellent results generally attained by some engineers and contractors that we should expect these results much more frequently.

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